AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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No. 857.

STREAM CONTAMINATION AND SEWAGE PURIFICATION.

An Informal Discussion at the Annual Convention, June 28th, 1899.

SUBJECTS FOR DISCUSSION:

(*a*) "Should Stream Contamination by the Sewage of Cities be absolutely prohibited by law?"

(*b*) "Should the Purification of the Sewage of Cities be Compulsory; and is this feasible for Large Cities?"

(*c*) "Is Filtration the coming solution of the Pure-Water Question for Cities?"

By Messrs. R. E. McMATH, W. C. PARMLEY, GARDNER S. WILLIAMS, PETER MILNE, KENNETH ALLEN, JAMES OWEN, CHARLES G. DARRACH, E. W. HARRISON, P. A. MAIGNEN, L. L. TRIBUS, PALMER C. RICKETTS, JAMES S. HARING and JAMES H. FUERTES.

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law is an already existing remedy, and has been applied in many cases which could be cited. Mr. McMath.

The presentation of this topic for discussion by this Society does not imply any doubt as to this recognized law, but, perhaps, is intended to call the attention of engineers to its existence and to the necessity for its extension to questions which, in this country, may arise between the people of adjacent States, if the defiled stream is a boundary, or passes from the territory of one State into that of another. That is to say, is there not a necessity for a general law which will embrace all States, and will settle all questions which arise between States?

Several of the States do exert their powers to prevent contamination of streams by the cities under their jurisdiction, but there is, as yet, no statutory provision to protect against contamination by the sewage of cities in other States. If, by the indifferent or mistaken policy of one State, its cities, great or small, are allowed to defile the streams, must the people of other States suffer for lack of adequate remedy?

The established law referred to has not been enforced in many cases where the transgressor is a city, but the transgression being for a time condoned does not establish a right to transgress for all time. As the country increases in population, the pollution of streams will increase and will quickly pass beyond possible toleration.

As the speaker views the matter, a law more imperative than any statute should control every engineer who has to do with the sewerage plans of cities; and he should foresee and provide for the disposal of sewage eventually, if not immediately, in another manner than by discharge in crude form into streams. Anything short of this is not worthy to be called a plan for a sewerage system.

The City of Chicago has for years been preparing a channel for the discharge of its sewage through its back door, so that this sewage will pass the front doors of other cities, and some of these other cities are not well pleased by the prospect, especially since the demonstration that certain diseases are water-working and that the pathogenic bacteria are tenacious of life. The topic under discussion would be an important one if Chicago did not exist, but the Chicago case gives much emphasis to the topic at the present time, for it is a scheme to do permanently, and on a large scale, what everyone must admit should not be done at all—a scheme which is to-day without an avowed designer and almost without a defender.

There was a time when many believed that the water of a river purified itself. Others firmly believed that dilution to a point beyond the reach of refined chemistry must render such water innocuous. The Chicago scheme had its origin when these beliefs were held. This scheme, involving the expenditure of more than $30 000 000, has progressed, notwithstanding the passing of the faith upon which it was founded, and now the only plea which is advanced for its consummation

Mr. McMath. is the fact that $28 000 000 and more have been expended on it and it is now too late for objectors to state their objections.

This brings up the consideration of the second topic: "Should the Purification of the Sewage of Cities be Compulsory; and is this feasible for Large Cities?"

The answer to the first part of this proposition follows that given for the preceding topic. If streams are not to be contaminated, the sewage must be purified; for water is the only known vehicle which can carry the wastes of human life and industry away from our homes and shops. That such can be purified, so that the effluent may be entirely unobjectionable, has been demonstrated beyond occasion for further discussion. How to do it, in each case that may arise, is the work of engineers, to plan, execute and operate.

There is no casuistry in the assertion that in this matter the end justifies the means, even when the difficulties surrounding the end require large and many means.

As to its feasibility for large cities there are too many old-world examples of successful solution for American engineers to hesitate as to the answer. It can be done, and we are the men who can do it.

The third topic comes in to round out the discussion: "Is Filtration the coming solution of the Pure-Water Question for Cities?"

Asked in connection with the preceding topic, the question may be taken as a suggestion that the sufferer from sewage contamination of water supply must protect himself, and thus relieve his up-stream neighbor of his obligation.

To meet this suggestion it is sufficient to mention the fact that the sufferers do not all live in cities, and are not able to protect themselves. There are evils from such contamination not measurable by the results of a bacteriological examination for specific microbes. There is also a contamination of water by the drainage of lands outside of cities which sooner or later will justify and even compel resort to filtration of the water supply of cities.

The doctors may say that they can cure a large percentage of cases of diphtheria, for instance, but the wise mother does not expose her children to infection on the chance that all cases in her family will be cured.

Therefore, filtration may promise a remedy for defiled waters, but that does not imply that the filtered water would not be better and safer had it not been contaminated.

Mr. Parmley. W. C. PARMLEY, M. Am. Soc. C. E.—The question of stream pollution is one that concerns almost every city. If no pollution of the water courses is to be permitted, then all the sewage must be purified, and the question resolves itself into one of expense. Small towns, or those of larger size, which are favorably situated, may adopt some method of ultimate treatment at comparatively small cost, but in the

case of many, if not indeed most, of the larger cities, the expense involved by such treatment would be a very great burden, if not altogether out of the question. Insistence upon absolute freedom from pollution would make the interception of sewage and the overflow of storm water an impossibility. Mr. Parmley.

The whole matter is one in which the ideal is set over and against the practicable—the desirable but extremely difficult to attain, against the less desirable but practically possible—but it is no more important that all the water we drink should be free from impurities than that the air we breathe and the food we eat should be pure and wholesome. To insist, however, upon a high degree of purity in a stream from which no drinking water is drawn, or at most only stock water, is to require heavy payment for very small benefits, and many streams have long since ceased to furnish even the latter supply.

The only other cases necessary to consider are those in which the odors arising from a polluted stream become unpleasant or harmful, or where the sight of turbid or colored waters or the refuse left by them along their banks is objectionable for æsthetic or sentimental reasons. The sanitary welfare of the people within the area affected is the ultimate and only condition to be insisted upon.

Even in the earlier development of our cities the natural drainage courses soon become so polluted by local discharge that no drinking supplies are likely to be taken from them, and it remains to be determined whether the pollution which has already occurred shall be removed or not. As most of this pollution is from factory wastes or from the washings of stables and privy vaults, it is a source of impurities nearly impossible to avoid. While the drainage area remains suburban, the cost of adequate sewerage would be too expensive to be borne by a sparse population or an isolated manufacturing company, and when the density of population becomes sufficient to make thorough sewerage possible, the soil and water-courses have already become so polluted that many years would be required to thoroughly drain them. Even then, as those who have had experience will testify, it is impossible to prevent entirely the clandestine discharge of some sewage into the streams. It follows, then, that the smaller courses which are not entirely taken into the sewerage system will have a considerable degree of pollution. Just the percentage which may be allowed is impossible to state, but it is dependent on the character of the polluting matter, the climatic and many other conditions. It is safe to say, however, that no stream should be permitted to become so befouled as to give off offensive effluvia and gases, thus showing that it contains a large amount of putrefying matter. Either, these streams should be diverted into the sewers, or the whole stream taken up in a large trunk sewer.

The question of permitting storm water from sewers to overflow into

Mr. Parmley. water-courses is important in many cities. If such overflows are not allowed, the cost of the sewers thus required, over that where the overflow system is permitted, becomes an item of no mean proportions. The engineering department of the City of Cleveland has at the present time a contention with the Board of Park Commissioners regarding the overflow of storm water from a sewer into a stream; and if it is finally settled that the sewer cannot be permitted to overflow, the cost of the sewer will be about $250 000 more than if it were constructed with storm-water overflows. In another instance the local court has issued a restraining order to prevent the discharge of excess storm-water into a stream which is already highly polluted. The final settlement of the case is of great importance, as upon this decision will depend other important projects in the sewerage of that city. The court apparently ignored the important facts brought out in the trial, viz., that this overflow would not operate except in case of excessively heavy storms, when the water would be discharged for perhaps 15 or 20 minutes, that these overflows would probably occur only a few times during the season, that the actual stream in time of flood would be nearly as impure as the water overflowed from the sewer, and that even if it were not, the time of maximum flood in the stream would be after the sewer had ceased to overflow and the stream would continue to flow with a large volume for many hours afterward, thus washing away the last traces of any fancied pollution.

If sewers are not allowed to discharge or overflow into natural water-courses, in many instances the double system of sewerage will become an absolute necessity. If the sanitary sewage be conveyed to a proper outlet through separate sewers and all the storm-water is to flow to the natural drainage channels, either through storm sewers or directly over the ground, the water discharged therefrom will usually be more foul than that which reaches them from the storm overflow structures of the combined sewers. As all engineers have probably noticed, the first washings of the street surfaces are extremely foul, and, by the system of overflows, this foul water is carried to the sewer outlet while a portion of the cleaner washings which occur later in the storm, mixed with the normal volume of sewage, will escape from the overflows into the stream.

If, however, the contaminating effect of street water be neglected and only the effect of sewage from the sanitary flow be considered, and if the entire volume of dry-weather flow in the sewer be defined as sewage, in the first case above cited it was shown that the maximum degree of pollution, that is, when the sewer is just at the point of overflowing, is 1 of sewage to about 7 of street water, and when the structure is discharging its maximum volume of overflow the proportion is 1 of sewage to 30 of street water. Now, consider the degree of pollution of the stream into which this discharge is made, and the

proportion of pollution is much less in proportion to the volume of water already flowing therein. Mr. Parmley.

It is a matter of the simplest observation to show that in many cases the water escaping from overflows in time of storm is not more foul than that in the swollen waters of the flowing stream. It being thus impossible to prevent the pollution of small courses flowing through thickly populated areas, it seems unwise to attempt to preserve in them a greater degree of purity than that required to prevent their contaminating the surrounding air, and when they are so short, or their velocity of flow is so rapid, that an outlet is reached at a point beyond which it is unnecessary to consider their impurities, and before those impurities have had an opportunity to decompose, the further expenditure of money, in order to preserve a high degree of purity, would be a needless waste.

The matter then suggests the following conditions, with their appropriate treatment:

1st.—Streams or bodies of water from which potable supplies are drawn should be preserved in the purity required by the most advanced sanitary science, and if such purity can be obtained in no other way, the supply should be properly purified before being used.

2d.—Streams or ponds which have sluggish motion with consequent tendency to stagnation should be kept as free as possible from sewage pollution in order that their emanations may be less dangerous.

3d.—Streams in which the flow is so rapid, or in which the courses are so short, that stagnation and decomposition are impossible within the limits of time necessary to consider, may be used advantageously for the overflow of excess storm water, or as the direct outlet for a limited number of sewers.

GARDNER S. WILLIAMS, Assoc. M. Am. Soc. C. E.—It would be interesting to determine, if possible, where to draw the line as to the limit of the stream which is not used as a source of potable water. Nearly all streams flow into others or into lakes, and at some point drinking water is being taken from them. Mr. Williams.

An interesting case came under the speaker's observation, while he was connected with the water supply of Detroit, Mich., which involved the investigation of a serious typhoid epidemic in that city in 1892.

Port Huron is situated at the head of the St. Clair River and at the foot of Lake Huron. The distance by water from Port Huron to Detroit is about 60 miles, about 18 miles of which is through Lake St. Clair, where the current is very slow, and which acts as a monstrous settling basin, giving ideal conditions for sedimentation and the consequent purification of the water. The sewage of Port Huron is discharged into Black River, a very sluggish stream, which flows through the center of the city and receives sewage from both sides. The current in Black River is practically nothing, except in time of

Mr. Williams.

freshet. No water for potable purposes is taken from this stream, but the Detroit and St. Clair Rivers and Lake St. Clair are sources of supply.

In 1890, Congress decided to improve the navigation of Black River, and work thereon began in 1891. Dredging was commenced at the bar at the mouth of the river, and was approaching that part of the river where the principal sewers discharge when cold weather stopped the work. On April 16th, 1892, work was recommenced at a point about 300 ft. below the first bridge, and at that bridge two large sewers discharge into the river. Below that bridge it is reported that a depth of 12 ft. was dredged through an accumulation of sewage deposits which had been gathering there for years. The inspector's records of the dredging show that there were excavations in such material 8 ft. in depth. This material was put in dump scows, taken out into the St. Clair River and dumped at a point over the Grand Trunk Railroad tunnel, or approximately 60 miles above the intakes of the Detroit Water-Works, which are just below Lake St. Clair, and virtually at the head of the Detroit River.

The record of typhoid fever in Detroit at that time is interesting. There had been some deaths from typhoid early in the year, but between May 11th and May 28th, 1892, no deaths were reported. On May 28th there was one death. On June 5th there were four, and during the ensuing 25 days there were thirty-seven deaths from typhoid fever, the population of the city being then about 230 000. The death rate from typhoid in that year in Detroit rose as high as the typhoid death rate of any large American city, except Chicago, Pittsburg, Jersey City and St. Louis, in the past ten years. There were three years in which the death rate in Pittsburg and two in which that of Chicago had been higher.

It was somewhat difficult to trace the cause of this epidemic, and when the speaker began his investigations he was not aware of the operations of the Government in Black River in 1891 and 1892. He therefore did not look there for the pollution, but began examining the river and studying rainfall, the effect of thaws, the effect of ice in the river and the character of the water. None of the ordinary methods of accounting for the presence of typhoid was applicable in this case.

The precipitation during April had been heavy, but it had also been heavy at many other times when there was no typhoid. During that summer all the river cities had typhoid, and in all cases the disease appeared at about the same time. At Port Huron, while there had been a tremendous excess of typhoid late in the fall of 1892, there were only one or two cases in the spring of that year; this pointed to a cause at or below Port Huron.

Finally, the speaker's attention was called to the Government

dredging operations and to the place where the material was dumped. The flow of the Detroit River is given as 225 000 cu. ft. per second. From all available information as to the velocity of the water, it was found that it would reach Detroit in not less than 6 and would probably require not more than 10 days. From a careful study of the statistics of typhoid fever, as published by various Boards of Health, the conclusion was reached that the average period of incubation was 14 days. An examination of the statistics as to this disease showed that death, when it ensues, ordinarily occurs between the twenty-first and twenty-eighth days, which would give 25 days as an average. From April 16th, the day on which the first scow load of polluting material from the sewers of Port Huron was dumped into the St. Clair River, until June 5th, when there were four deaths from typhoid in Detroit, is 50 days. If 10 days are allowed for the water to flow, 14 days for the disease to incubate and 25 days to kill, the total is 49 days. Mr. Williams.

The investigation was carried on throughout the summer, and the curves of secondary and tertiary infection were studied, and finally, about seven weeks after cold weather set in and dredging operations were suspended, the typhoid ceased. Next year the typhoid appeared again after the dredging had commenced, and when it stopped the disease disappeared. These conditions have followed one another since that time, and investigations have shown that they prevailed in previous years. Going as far back as 1886, it was found that typhoid appeared during those years when dredging operations disturbed the channel of the St. Clair River or Lake St. Clair above the intake of the Detroit Water-Works, even as far away as Lake Huron; and the relationship could be traced accurately. In one or two years, when there has been no disturbance of this channel, Detroit has had a very low typhoid death rate.

Another interesting case occurred in 1897, which was a year of very low typhoid in Detroit, the rate being only 1.1 per 10 000 living. During that year there was only one group of cases which could be considered as epidemic, and that came in August. In two weeks there were seven or eight deaths. In looking for the cause it was found that the Government was dredging in the Clinton River. The work had been commenced some time before, and the dredge had been working gradually up the river, the material being dumped in Lake St. Clair, in what was supposed to be stagnant water, at a point about 16 miles from the water-works intake. At a certain date the dredge arrived at a bar in the river just below Mount Clemens, a town which, though not having a complete sewerage system, has a few sewers discharging into the Clinton River. A computation, similar to that previously described, showed that the group of cases in August was due to infection stirred up by these dredging operations.

Mr. Williams. These instances are given for the benefit of those who speak of streams which are not used as sources of water supply. There is no stream which is not a source of water supply for some person or community, and there is no danger of going too far in the restriction of the pollution of our streams.

Mr. Milne. PETER MILNE, Assoc. Am. Soc. C. E.—The American Water-Works Association has had the subject of stream pollution under consideration for the past eight years. Judging from correspondence with State Boards of Health and eminent medical authority, the speaker is led to believe that interstate legislation will not accomplish the object sought; and that it will be necessary to appeal to the Congress of the United States to seek the enactment of national laws to prohibit the pollution of water supplies. Such law may of necessity guard riparian rights and also protect the health of the people using the water of streams liable to be contaminated by sewage of every character.

A special standing committee of the American Water-Works Association has nearly ready for publication a voluminous report upon this subject.

An expression of opinion upon this important question by this Society will carry weight and influence and be accorded the consideration due.

An example of the manner in which a community may recede from its position taken regarding sanitation of water supply, is afforded by the experience of the City of Brooklyn, N. Y. More than four years ago, two streams, which formed a part of the daily supply, were condemned by the Board of Health of the City as unfit for use, on account of pollution due to the sewage of the population dwelling upon the water sheds, which pollution had increased yearly in proportion to the increase of population. These stream supplies were abandoned. In the present emergency and extremity of the city, viz., a long drought, it is suggested to again use the water of these streams, provided it is filtered.

The question of filtration being one of degree, it is apparent that its range of effectiveness in application is contingent upon the measure of pollution to be met and treated. If pollution is permitted to increase in intensity as well as quantity, it is reasonable to assume that the cost of filtration would be prohibitory and compel the consideration of new sources of water supply remote from the influence of pollution.

If the Federal Government enacts laws which in effect restrict pollution and contamination of the waters which are used by the people, it must invoke the skill of the engineer to aid it, on the one hand, and wise legislation, on the other hand, in order that equitable relations may be established and that the rights of all interests may be safeguarded in the effort to prevent the defilement of water supplies.

KENNETH ALLEN, M. Am. Soc. C. E.—In studying questions relating to stream pollution it is natural to turn to England, where, in official reports on the subject, there is a storehouse of information which is not to be found elsewhere; although of recent years the investigations undertaken by several States—notably Massachusetts—and by several cities, have made available much information of the greatest value. Increasing density of population, the concentration of large industries, and a general awakening of the masses to the importance of their sanitary environment, all serve to direct attention to the matter of stream contamination. Mr. Allen.

Up to the present time, the most important legislation on the subject has been the Rivers Pollution Act of 1876, resulting from a report of the Second Rivers Pollution Commission on the Rivers Mersey and Ribble, in which the following requirements, especially regarding organic pollution, which had been recommended by Dr. Frankland, were adopted:

"We suggest that the following liquids be deemed polluting and inadmissible into any stream:

"(*a*) Any liquid containing in suspension more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter, in 100 000 parts by weight of the liquid.

"(*b*) Any liquid containing, in solution, more than 2 parts by weight of organic carbon, or 0.3 part by weight of organic nitrogen in 100 000 parts by weight.

* * * * * * *

"(*f*) Any liquid which, after acidification with sulphuric acid, contains, in 100 000 parts by weight, more than 1 part by weight of free chlorine.

"(*g*) Any liquid which contains, in 100 000 parts by weight, more than 1 part by weight of sulphur, in the condition either of sulphuretted hydrogen, or of a soluble sulphuret."

Although adequate provision for the enforcement of this Act appears not to have been made, its requirements were probably as fair and sound as was possible with the scientific knowledge of that time.

In the same year, 1876, the Massachusetts State Board of Health presented, in its annual report, a number of recommendations regarding the discharge of crude sewage into streams; among them:

"That no city or town shall be allowed to discharge sewage into any water-course or pond without first purifying it according to the best process at present known, and which consists in irrigation; provided that this regulation do not apply to the discharge from sewers already built, unless water supplies be thereby polluted; and provided also that such intended discharge can be shown to be at such point or points that no nuisance will arise from it."

But they are careful to add, that:

"The Board feels that, in the present state of our knowledge, sweeping laws for the general and immediate purification of all our streams would be hardly justifiable, and that they are not called for by the present condition of our rivers."

Mr. Allen. In the 23 years which have elapsed since these views were officially expressed, there has been opened up a vast field of research in sanitary matters, through the science of bacteriology, and, as our knowledge of the life history of these minute organisms is as yet quite imperfect, we are not likely to arrive at the ideal treatment of the matter for some years to come.

The standard of purity for sewage effluents, as established by the Second Rivers Pollution Commission, is faulty in the following particulars:

In the first place, the nuisance caused by a foul effluent depends quite as much upon the character of the stream into which it flows as on the effluent itself. A foul effluent discharged into a deep, swift-running stream of well-oxygenated water may cause no offence, while an effluent of half the size and twice the purity of the first, meandering over mud flats to a sluggish brook or mill pond may prove highly objectionable.

It is, therefore, seen that, if a standard of purity for the effluent is to be fixed, it should be in some way correlated to the character of the stream itself, and this under its most unfavorable conditions, as at extreme low water, when covered with ice, or when, for some other reason, it is particularly foul or devoid of absorbed air.

The two following examples serve to illustrate the inconsistency in the standard alluded to.

At the Leeds Congress of the Sanitary Institute of Great Britain, in 1897, Professor A. Bostock Hill, wishing to accentuate the difficulty of attempting to fix a standard for sewage effluents, quoted a case:

"Where a tank effluent, without any preliminary treatment, gave better results than the Rivers Pollution Commission standard, and yet subsequently so seriously polluted a stream that an injunction was applied for and obtained."

On the other hand, Alderman J. F. Spence (Chairman, Tyne Port Sanitary Authority), said:

"Between Tynemouth and Newcastle-on-Tyne, a distance of ten miles by the river, there is as large a number of works discharging foul and poisonous effluents as probably on any other stream in the kingdom. But these are so largely diluted by the enormous influx of sea water twice in the 24 hours, the difference in time between high water at the bar and Newcastle Quay being only 17 minutes, that the late Dr. Frank Buckland, when inspector of salmon fisheries, quoted the Tyne as one of the best salmon rivers in the kingdom, the pollutions being so diluted that the fish passed there unscathed to their spawning grounds in the higher reaches of the river. It may therefore be said the pollutions cause no nuisance, as the tide clears them all away."

Again, the Rivers Pollution Commission standard fails to appreciate the potential capacity for further purification in the effluent itself. This important point has been brought into prominence by the difficulty in securing permission, under existing laws, to discharge

the effluents from certain bacterial treatment plants into neighboring streams, although it is generally admitted that no nuisance would result thereby. The outcome of this is that a Royal Commission has been appointed, and is now giving this matter careful study, which will no doubt end in placing before the world most valuable and complete information on this subject. Mr. Allen.

The final purification of sewage, which is due to the mineralization of its organic constituents, is effected by the action of minute organisms, either vegetable or animal, but generally by bacteria, and this is the case with crude sewage, the effluents from chemical precipitation works or from sewage farms, as well as from the septic tank or other of the methods known more specifically as bacteriolytic. To interrupt this action by the use of antiseptics simply postpones the inevitable and desired result, allowing organic matter to accumulate. Such interruption is, therefore, fundamentally wrong.

The process of mineralization may be roughly considered as taking place in two stages.

In the first stage, the solids are broken up and thrown into solution by liquefying bacteria, while the rearrangement of the molecules of all the organic matter renders it more susceptible to further change. This action is called bacteriolysis, and it takes place in a comparatively short space of time, the characteristic product being carbon-dioxide. Although usually occurring under anærobic conditions—when it is often accompanied by the evolution of sulphuretted hydrogen, marsh gas and other offensive or dangerous compounds, and sometimes, very likely, by the formation of those virulent poisons known as ptomaines—it is pointed out by Dr. Samuel Rideal as quite probable that it may result from the action of such ærobic liquefying bacteria as *B. Prodigiosus* and *B. Liquefaciens* under suitable conditions.

In the second stage, which is marked by oxidation of the nitrogen, and known as nitrification, the bacteria essential to the process must be supplied with oxygen, and it is characteristically an ærobic process.

It is true that in the formation first of nitrites and then of nitrates the oxygen required for the former may, in the absence of free oxygen, be wrenched from the nitrates or from other combinations of oxygen, leaving the final conversion into nitrates to be effected later.

Dr. Walter E. Adeney, of Dublin, has taken advantage of this action in devising the method of sewage and sludge purification known as the "Oxygen System," in which nitrification is effected by the application of nitrate of soda or permanganate of potash, substances which are capable of furnishing the oxygen required.

Nitrification is a comparatively slow process, and, while accomplished in an ideal manner by intermittent filtration, yet by reason of its slowness it may often be effectively carried on in streams by means of the oxygen dissolved therein. When, however, this element is not

Mr. Allen. absorbed from the atmosphere as rapidly as it is taken up by the organic matter undergoing purification, anærobic conditions prevail, which we call putrefaction, with their attendant evils.

It is clear, then, that the ability of the stream to oxidize the impurities in an effluent is a most important consideration, which has been quite ignored in the standard set by the Second Rivers Pollution Commission.

The determination of the organic nitrogen and carbon, as proposed by Frankland, has been found difficult in practice, and has been largely superseded by the less precise but more practicable determination of (or test by) albuminoid ammonia, as proposed by Wanklyn, or of the oxygen consumed, as proposed by Forschammer, or by both of these together.

Messrs. Pearmain and Moor have recently proposed the following standard, as adapted to present needs:

	Parts per 100 000.
Total suspended matter (not to exceed).....	2.0
Albuminoid ammonia "	0.2
Oxygen absorbed "	0.714
Total hardness "	28.57
Nitrogen as nitrates (not to be less than).....	0.714

They insist on the last requirement for the reason that, besides indicating the completion of the process, the nitrates also indicate a store of oxygen which may be drawn upon to oxidize the remaining impurities, insuring thereby a guarantee against putrefaction.

Dr. Rideal, to accomplish the same end, has suggested, as a safer test than any previously proposed, "the ratio of the oxidized nitrogen in the form of nitrate and nitrite to the 'oxygen consumed' figure," as the former represents the oxygen available and the latter the oxygen required to carry out the process of purification. He states as his belief that when the available oxygen is in excess,—

"Then under no subsequent conditions would a reversion of the sewage take place so as to cause a nuisance, and such a method of valuing the suitability of an effluent was independent of the size of the stream or the dissolved oxygen it contained. When, and in the majority of cases this was the case, the stream was many times the volume of the sewage and contained dissolved free oxygen, then this free oxygen was utilized instead of the oxygen of the oxidized nitrogen. Under these conditions it was not necessary for the oxidized nitrogen as compared to the 'oxygen consumed' figure to be so large."

If the character of a proposed effluent, as well as its probable dilution in running water, could be predicted with certainty, its liability to cause offense could be pretty well foretold. A rough but convenient limit was determined in this way by F. P. Stearns, M. Am. Soc. C. E., when Chief Engineer of the Massachusetts State Board of Health, substantially agreeing with a similar limit fixed by Rudolph

Hering, M. Am. Soc. C. E., with reference to Chicago's sewage discharge, in which he designates a stream flow of not less than 2½ cu. ft. per thousand population as sure to cause offence, and a flow of over 7 cu. ft. per thousand population as not likely to cause offence. Mr. Allen.

Such a rule will, of course, apply only when manufacturing wastes are negligible in quantity or character; but where questions involving the dilution of crude sewage are concerned, this method of predicating offensive conditions is likely to prove as convenient and satisfactory as any, considering the number of indeterminate factors involved.

Whether more definite tests, to cover various conditions, are practicable remains to be seen, but the more recent ones appear to be steps in the right direction. Possibly the future may discover some simple biological tests by noting the effect of polluted streams upon various kinds of fish or other organic life contained in them. In fact, in the elaborate series of experiments on sewage disposal which has been carried on for several years past at Leeds, one test of certain effluents was their capacity to support the life of carp, the effect on confervoid growths being also noted. It is known that different kinds of fish, such as salmon, bass, catfish and menhaden, require waters of different degrees of purity, and their survival would, to a certain extent, be a measure of the contamination of the water in which they were placed.

A great economic advantage in bacterial treatment is the elimination of the vexed question of sludge disposal. It is true that sand and other grit still have to be removed, and that woody fibre requires time to become peptonized without clogging the filter, but the troublesome and offensive organic solids may be effectually disposed of, and this is a great step in advance.

The relative efficiency of such treatment, as compared with mechanical filtration and chemical precipitation, is well illustrated by the following results obtained at Leeds:

	Oxygen Absorbed in 4 Hours.		Albuminoid Ammonia.	
	Parts per 100 000.	Percentage purification.	Parts per 100 000.	Percentage purification.
Crude sewage	12.14	....	1.21	....
Filtration through paper	5.53	54	0.67	45
Lime precipitation	6.57	46	0.64	47
Bacterial action (Dibdin's filters)	0.91	92	0.125	90

Crude sewage contains several million bacteria per cubic centimeter —London sewage some 3½ million. After complete nitrification, these are reduced to an insignificant number; but before that time, although an effluent may contain sufficient oxygen to complete the process of purification, it may contain a very large number of these organisms.

Mr. Allen. Now, while there is some evidence to indicate that pathogenic varieties will have been eliminated before arriving at this stage, yet with the present imperfect knowledge, and with the possibility of their subsequent introduction into an effluent yet containing nutrient material, it would probably be wise to fix a low limit to the bacteria per cubic centimeter permissible in a stream used for a water supply which has received the effluent from biological filters. In fact, it is a question whether the water of such a stream should not be filtered before distribution to a city, as there is always a chance that at times, through accident or excessive flow, the purification of the sewage may not be up to the established standard.

When the stream is not used for drinking purposes, the presence of a large number of bacteria in the effluent is not necessarily an unfavorable indication.

It is believed that, for the present, legislation regarding stream contamination and sewage purification should be largely tentative, both because experience in these matters is as yet limited, and because it is rapidly increasing.

In dealing with a subject so complex and, at the same time, often involving the public health and the outlay of large sums of money—in the establishment of purification works on the one hand and the depreciation of riparian property on the other—each case of pollution should be considered by itself, by an authorized official, who should be a man of much tact and ability, as well as one having special knowledge and experience in his line. He should be guided by certain general laws regarding stream pollution, but should be given considerable discretionary power, and, to avoid troublesome changes of policy, it would probably be well to have him serve a long term of years. On the other hand, he should not be enabled to use his authority in too summary or arbitrary a way, to the disturbance of vested interests, when not absolutely necessary for the public good.

In order to make his supervision effective, the area under his control should be defined by the natural water-shed lines; that is, he should have authority over the entire drainage area of one or more streams, and be responsible for their condition.

In order to effectively control stream contamination, it is suggested that all streams may be placed in one of three general classes, viz.:

I. Streams far from populous centers and not likely to be used for manufacturing or domestic purposes.

II. Streams likely to be used for other than domestic purposes.

III. Streams likely to be used for domestic purposes.

Such a classification would not appear to be difficult or intricate, and laws regarding permissible pollution would apply, in general, to all streams of the class in question. Class I would require little or no legislation, while certain standards of purity for sewage effluents,

etc., would apply to Class II and others to Class III. Moreover, in the case of large rivers, like the Mississippi or Hudson, it would be quite possible to include the headwaters and upper reaches in Class III and leave the lower reaches in Class II. On the other hand, if certain populous centers toward the mouth of the stream should befoul its waters to the detriment of the fishing or other interests near by, it might be necessary to create a special district to which the restrictions for Class III would apply. Mr. Allen.

That the purification of the sewage of large cities by land disposal is feasible, is seen by such examples as Berlin and Paris.

Suitable land, however, is not always available, when chemical treatment, followed by filtration through the natural soil, as at Birmingham and Manchester, or through prepared filter beds, as at Glasgow and Sheffield, may be resorted to. In the cases of London and Salford, the sewage is merely clarified by chemical precipitation, and the sludge is carried out to sea by steamers and dumped; and in such cases the effluent cannot be said to be truly purified. The previous examples, however, suffice to show that there is no inherent difficulty in purifying the sewage of a large city, even if irrigation cannot be availed of. It is merely a question of selecting the best and cheapest.

The modern bacteriolytic processes avoid the acquirement of extended areas for irrigation on the one hand and the question of sludge disposal on the other, and from them the ideal solution of the sewage disposal question of the future may be hoped to be realized. Experience has already been sufficient to obtain for these methods very high endorsement.

For instance, in testimony before a Local Government Board Inquiry at Exeter, regarding the septic tank treatment, Dr. Rideal gave as his opinion, that

"Wherever a sewage farm would work, this system would work, and anything which would prevent this system working would prevent a sewage farm working."

When asked whether it could be applied to very much larger towns, he replied "much larger." Dr. Dupré, also, declared that "no system of purification hitherto known had such a complete effect upon sewage."

It must be admitted, however, that up to the present time no great city uses any of these methods. The largest plant is at Sutton, England, where some 145 000 U. S. galls. per day are treated by the Dibdin system of double filtration.

The Sewerage Commission of the City of Baltimore, which for some time has had this very matter under consideration, while admitting the admirable results attained at Sutton, Exeter, and elsewhere, and after consultation with Mr. James Mansergh, regarding this particular point, has refrained from recommending any one of these sys-

Mr. Allen. tems for so large a city, involving, as it must, much that would be new when applied on the scale proposed. But this decision is qualified by the statement that

> "The Commission fully recognizes that one or more of them may prove available for the treatment of the sewage of some of our outlying districts, and may, if future experience sustains the claims and anticipations of their advocates, yet become adequate to our service on a larger scale."

To sum up what has been said, it is believed:

(*a*) That stream contamination should be prohibited, and the purification of the sewage of cities be compulsory only:

(1) When it is offensively evident to the senses of smell or sight.

(2) When manufacturing, fishing, or other productive interests are likely to be seriously affected thereby.

(3) When the health of neighboring communities is jeopardized, either through the authorized use of the stream for domestic purposes, the probable contamination of areas devoted to the culture of shell-fish, or the probable formation of deposits upon shoals or shores.

(*b*) That the purification of the sewage of large cities is always feasible. It is always costly, but it is probable that the introduction of bacteriolytic methods of treatment will, in general, when more fully developed, tend to economy.

(*c*) That to make legislation effective:

(1) All streams should be classified according to their permissible contamination.

(2) A responsible officer should supervise and control all sources of pollution throughout the drainage area of every stream in which pollution is restricted by law.

(3) Where possible to formulate consistent regulations regarding the limits of contamination, this should be done; but that with regard to organic contamination, in the present imperfect but advancing state of our knowledge on this subject, the matter may best be left largely to the discretion of the official in charge of the particular drainage area in question.

Mr. Owen. JAMES OWEN, M. Am. Soc. C. E.—It has not been regarded as within the province of this Society to discuss legal questions, but, recognizing legal enactments as the crystallization of public opinion on the subject legislated upon, the legal aspect of stream pollution is worthy of consideration. The radical, unqualified proposition that all pollution of streams should be summarily stopped seems to the speaker unwise. The question is a very live one in New Jersey, and the conditions in the northern part of the State furnish an object lesson.

Mr. Owen.

The Passaic River was formerly known as "the beautiful Passaic;" now it is called "the dirty Passaic." Along its banks is a population of about 400 000 persons, who, by the construction of sewers, have completed, within the past twenty years, a system of discharge which renders the river unfit for potable uses, or for any purposes for which water can be used. Until three years ago, Jersey City took its water from the lower Passaic. It was bad water, much contaminated and unfit to drink, and Jersey City vainly tried, for years, to obtain from the Courts means to restrain the towns above its intake from discharging their sewage into the stream.

Newark obtained a new water supply about ten years ago, and Jersey City got a new supply three years ago. Curiously enough, as soon as Jersey City stopped taking its drinking water from the river, there arose a popular demand that the pollution of the river should cease. Paterson, with 100 000 population, is discharging a large amount of sewage into the river, and Newark and the towns between Newark and Paterson wish defilement from this source prohibited. Newark also discharges an enormous amount of sewage into the river, and this drifts up with the tide for four or five miles above the city.

On the Upper Passaic is the small town of Summit, which is discharging into the river, not crude, but filtered, sewage. The City of Paterson has brought suit against Summit to prevent its pollution of the stream. As a kind of cross-fire comes the proposition of the City of Paterson to enjoin the East Jersey Water Company from taking water from the river, on the plea that there will not be left in the river sufficient water to take the city's sewage down. From this it will be seen that the trend of public opinion in that locality is indefinite.

It cannot be too strongly emphasized that there should be no contamination of drinking waters or the sources of such waters; but the matter of the discharge of sewers into rivers used merely for navigation, or for drainage, should be considered as a question of dilution; and if, within the next few years, a standard of permissible dilution, which would be free from effects deleterious to the community, can be established, the prime object of this inquiry will have been attained.

Mr. Darrach.

CHARLES G. DARRACH, M. Am. Soc. C. E.—The study of this problem for twenty-five years leads the speaker to agree with the conclusions so admirably expressed by Mr. McMath. The engineers of America are competent to solve this problem, and the speaker anticipates not only its solution but such a development in the future as will modify the water-supply question to the extent that if necessary a city will not be obliged to go beyond the purification of its own sewage to supply itself with water.

Mr. Harrison.

E. W. HARRISON, M. Am. Soc. C. E.—The subject of the right of cities on tidal streams to discharge their sewage therein has not been taken up in this discussion, but some recent events indicate a disposi-

Mr. Harrison. tion to impose unnecessary and harmful restrictions on such communities. When the City of Newark was founded, about 200 years ago, the site was chosen because it was on a tidal stream. It offered, by reason of its location, advantages for settlement, for manufactures and for commerce. This agitation for the purification of the Passaic River, of which Mr. Owen spoke, resulted in swinging the pendulum far from the stand taken by the Courts ten years ago, for in March last the City of Newark was enjoined from draining about 130 acres of land into the Passaic at a point where the tide ebbed and flowed. The water at this point was salt, though not as salt as the sea, but both medical testimony and a bacteriological examination were submitted to show that the growth of bacteria was inhibited by reason of its saltness. The river was thus acting only as a carrier, conveying sewage to the sea without affording opportunity for the further growth of bacteria.

That agitation and decision are now bearing strange fruit. Other towns draining into estuaries of New York Bay are seeking places of deposit for their sewage, and they can keep their water supplies pure only by turning their sewage into the tidal streams. This decision has helped to create the opinion in northern New Jersey that no sewage should be emptied into any stream, tidal or otherwise, not even into the Kill von Kull, a tidal strait between Staten Island and New Jersey, passing an enormous quantity of water with a swift current.

The recognition of this argument as a governing principle would operate to deprive cities located on estuaries and tidal streams of one of their great advantages as manufacturing sites. If a manufacturing plant cannot be established along the Arthur Kills, or a large city grow up there with the right to discharge sewage into the salt water; if investors in such enterprises must contemplate an enormous bond issue to take care of sewage, the manufacturing plant or the city might as well be located up in the mountains. Engineers will discriminate between drainage into salt water and drainage into a fresh-water stream, and, while the speaker agrees with Mr. Owen that the pollution of streams now used or likely to be used for water supply should be prohibited, the same arguments do not apply in the case of tidal streams; otherwise sewage purification works would be required for cities like New York and Brooklyn.

Mr. Maignen. P. A. MAIGNEN, Esq.—In Paris the distribution of the water supply is double and of two qualities; raw river water for industrial purposes, street sprinkling, fire extinguishing and other base uses—sold at 12 cents per 1 000 galls.; and spring or assimilated (filtered) water for drinking and household purposes—sold at 24 cents per 1 000 galls.

The potable water distribution, being kept at a higher pressure than the industrial water, became largely used for hydraulic elevators and other purposes as motive power. In order to discourage this

misuse of the pure water, the rate for such purposes was raised to 48 cents per 1 000 galls. This differential rate has prevented the abuse of the pure water, so that filtration plants have to be provided only for water legitimately used and well paid for. Mr. Maignen.

Another reason for which French engineers advocate the double canalization system is to maintain an even pressure in the pure water distribution, so as to reach the highest points of the cities at all times. It is customary, in many towns, to water the streets and flush the sewers, for several hours every day. With a single canalization the upper parts of the city would be deprived of water by the simultaneous opening of the low-town hydrants; this trouble does not occur with a double canalization.

Filtration, as an art, is still in its infancy. It is a mistake to ask too much of a single filtering operation. The work should be divided. Something has already been accomplished in this direction by the use of storage reservoirs, but unless they are, as in London, large enough to render pumping during storms unnecessary, they are only extensions of the river, and of little use. If storage reservoirs are wanted in case of accidents to the pumps, by all means build them, but, in the speaker's opinion, clarification can be obtained equally well by quick upward filtration through coarse sand or other coarse material—the choice varying according to the particular quality of the water to be dealt with—and at less expense.

Sand filtration, as carried on in Europe, with sundry improvements, could be applied as a secondary operation. And it is possible to find, in the large industries, such as sugar and chemical works, breweries, wine producers and the like, which have recourse to filtration, some ideas which may be of service in carrying out a third and final operation in the purification of water for city supplies.

L. L. Tribus, M. Am. Soc. C. E. (by letter).—For twenty years past the providing of suitable water supplies for thickly settled districts has been receiving more and more intelligent consideration; the relation of physical health to the wealth and efficiency of a community has been more carefully studied from the economic as well as the æsthetic standpoint; and to the ends at issue have been brought the brains, energies and conscientious efforts of engineers, chemists and even of municipal officials themselves, who have been popularly classed as men devoid of other than political instincts. Mr. Tribus.

To a more limited degree, the disposal of the wastes of civilized life, passing off as sewage, has received careful attention, and is beginning to be treated as it deserves, as one of the most important subjects for the engineer to consider. It is not alone necessary to provide human beings with pure food and drink; it is equally necessary to remove the refuse after the valuable parts are used.

The questions presented for these informal discussions, relating to

Mr. Tribus. Stream Contamination by Sewage, Purification of Sewage, and Filtration of Water, are so correlated as to make their separation here scarcely wise, although certain features of each are distinct.

By far the larger number of cities (the term "cities" including all communities making use of municipal systems of water supply or sewerage), take their supply from rivers or lakes, larger or smaller as the case may be; those using the various forms of driven and artesian wells not, as a rule, having the classes of waters that need artificial purification. This being the case, it is evident that the source of supply should be maintained in all possible purity, rather than that the water should be permitted to deteriorate, and then need to be purified by some form of filtration, and at great expense.

Consequently, defiling matter, as certainly raw sewage must be considered, should not be admitted to a lake or stream if there is any possibility of injuring the water supply of another place. There is no justice in permitting one community to save itself trouble and expense by entailing trouble and expense on another, or in event of that other not having sufficient enterprise to protect itself, and perhaps furnishing to it elements of disease and danger. Rights to the waters of a stream have caused litigation for centuries, but it is only in comparatively recent times that "use" of the stream has been considered as requiring, morally, if not always legally, passing it on in unimpaired purity.

Certain classes of sicknesses known as "Filth" diseases, of which typhoid is the most prominent, are usually attributed, and probably with justice, to the dissemination by the water supply (or milk, directly associated, too often, with it) of germs contributed by sewage to the sources of the water system. Dilution of sewage with water has been largely looked upon, even by engineers, as a means of purification, and to some extent it is, but dilution does not destroy germs; and disease germs in a large volume of water have just so much more chance of dodging the other forms of bacterial life which seek to destroy them.

Not many years ago, purification of sewage was not an unmixed success, chiefly because of unintelligent design and carelessness in the operation of plants, the method of Nature's action not being entirely understood, or, if so, then ignored; the germ theory had scarcely been promulgated, and the existence of bacteria of different kinds, which, like people, preyed on each other, was unknown.

It would be a difficult matter to estimate in dollars and cents the losses of property, the destruction of valuable material, and the injury to lives, directly traceable to the emptying of crude sewage into streams; yet few will deny that the aggregate sum would be vast. The driving away or destruction of fish life, removing thereby a very valuable article of food; the depreciated value of property adjoining such sewage contaminated streams, and the actual deaths of hundreds or

thousands of human beings, from the use of polluted waters, sufficiently indicate the conditions at stake. The latter topic has been so admirably covered in recent papers on typhoid and allied diseases, with their relationship to water supplies, that merely speaking of the remarkable reduction in death rate, noticeable after the introduction of pure supplies, is all that is necessary here. Mr. Tribus.

The New York State Board of Health, in its policy of saving streams and lakes from further contamination, practically compelling cities to treat their sewage, seems to the writer to have taken the only proper action that justice and right can countenance; yet there are instances where such exclusion would appear an unnecessary precaution, for the rights of no one would seem to be injured by "direct" disposal.

It is a question, therefore, that had best be left to the intelligent and more enlightened sentiment and judgment of communities directly concerned, trusting to fully sufficient existing laws to prevent undue trespass on the rights of others. The writer believes, however, that the proportion of sewerage systems to be constructed in the future, without adequate disposal and purification plants, will be very small; and that a large number of the systems now in use will ultimately require treatment.

The same discussion applies very largely to the second question—"Should the Purification of the Sewage of Cities be Compulsory?" Present laws or court decisions cover fully all cases where non-treated sewage becomes a nuisance to residents of the city itself or to those of other places. Unfortunately, enforcement of laws seems to be a very difficult matter, and there is no reason to suppose that any new laws, even apparently more binding, would work to any greater advantage.

As far as applicability to large cities is concerned, new questions always arise. In almost all instances, large cities have grown up on the shores of tidal harbors, great lakes or large rivers, so that sewage flow bears usually so small a proportion to the volume of moving water, fresh or salt, that the dilution dissipates most of the cause of offence, though in the course of years, unmistakable and permanent indications of defilement can be noticed near the outlets of the sewers.

It is necessary to note clearly, what purification of sewage actually means. It is the total resolution into harmless inorganic elements, of all defiling or organic matters—a complete chemical combustion or oxidation. In this process, bacteria, abounding in the sewage itself, have a great deal to do; in the opinions of some, perhaps more than any other agent.

A direct answer as to its feasibility for large cities is impossible; each city must be judged by its own conditions. New York, Philadelphia and Chicago would illustrate the impossible, or at least, impracticable. Paris has, in a large measure, successfully embraced purification. London aims to make the effluent inoffensive, but it is

Mr. Tribus. far from being purified; its chemical treatment and subsidence being only an arresting of Nature's processes, and not a completion of them. To a thorough understanding of this last subject must those come who have the handling of sewage problems. Nature cannot be hurried, though she enjoys being assisted. We must conform to her laws or failure will ensue.

It is possible to purify sewage, and it is practicable, but it takes land in large areas to do it economically, and land properly selected and prepared, with the utmost care in its use, besides; or it takes water in such large volume that the same processes of nitrification and oxidation can be carried on without regard to time, and be conveyed away by currents or streams, so as to be inoffensive during the operations. The methods of treatment need not enter into this discussion; but it must be borne in mind that, unless local conditions absolutely prevent, some form of land treatment, without the use of chemicals, comes nearest to Nature's own most efficient process, and consequently is most likely to prove successful, even under severe climatic conditions.

Closely allied to the purification of sewage, and even more important to human life, is the providing of pure water supplies. Mountain lakes and brooks in uninhabited or sparsely settled districts can usually be taken as of sufficient purity, if the water be intelligently gathered and cared for.

The trend, however, of growth of population, is in the grouping of communities along the courses of the larger streams and on the shores of lakes. This entails more care in the selection of intake points, and is gradually tending to make undesirable the use of neighboring waters for public supplies without treatment before use. On the other hand, the smaller streams and lakes, not subject to pollution, do not furnish sufficient quantities of water for the larger cities, even when storm-waters, in addition to normal flow, are carefully conserved. It is not always feasible to secure ground-water or rock-well supplies, nor are such waters always safe or desirable themselves, so that recourse must be had in most cases to surface sources. Most persons will grant that a surface supply, from unimpeachable collecting grounds and stored in well-kept, clean reservoirs, is all that can well be desired, but in the more closely settled States, each year, such a condition is becoming much harder to find. Then, again, in the use of surface waters in their natural state there is always somewhat of an uncertainty, for, in spite of the most careful supervision of the water-shed, unless it be absolutely uninhabited, contaminating elements are always likely to appear.

The writer is not quite ready to insist that all public supplies be filtered, for here, as in sewerage questions, situation has a great deal to do with the method proper for adoption; but certainly, intelligent filtration never harms a water, while its lack may entail danger. Fil-

tration, in some form or other, undoubtedly began with man's use of water; its adoption, on strictly scientific lines for public use, is a development of very recent years. We may neglect consideration of the small household filters, the thousand and one devices that improve or injure the water according to the care in their use, and take up the broader field of filtration of municipal supplies as a whole, by the two general systems which may be classed as "Chemical" and "Natural." Mr. Tribus.

It is unnecessary here to discuss the comparative merits of either. It is sufficient to say that both have full fields for operation, the main point being that it is fully proven that impure waters can be filtered and rendered safe and desirable for domestic use. At the present day practically everything is measured by its value in dollars and cents, a materialistic theory which we have to recognize even while combating it as a principle, so that the *pro* and *con* of filtration for any particular city seems to be: Does the advantage of a purer water, in decreased death rate of population, figuring life at a minimum value, or a gain to the community of the work of so many persons annually, equal the operation, interest on cost and appropriations for a sinking fund for a filtration plant? Of course, taxes and politics, and various other, often conflicting, interests are also considered; though impaired health, more or less discomfort, and offensiveness to eye and nose, seem to have but little weight. Usually the activity of a violently deadly epidemic is necessary to impress the weight of the argument.

The writer is amply convinced that the coming solution of the public water question, considered as a whole, is in "purification," implying rather more than the narrower term "filtration," though that, in its growing ordinary acceptation, includes the very complex operations of Nature which result in thorough purification, hence safety for the health of, and satisfaction in other uses by, the public at large.

PALMER C. RICKETTS, M. Am. Soc. C. E.—(by letter).—The great value and advantage of maintaining, if it were possible, all streams, large and small, in the purity they exhibited before there were settlements upon their banks is self-evident. The fact, however, remains that, to a greater or less extent, streams always have been and always will be natural sewers. They will be as long as water keeps flowing from the land into them and carrying with it impurities dangerous to health. Those flowing in thickly populated valleys certainly will be, even if the ordinary sewage of the cities on their banks be purified before being discharged into them. The fæcal matter of one inmate of one farm house may cause more havoc than a year's sewage flow from a large town. Mr. Ricketts.

As an example, consider the Mohawk River Valley in New York; narrow, with a long line of villages, towns and cities along its banks, and elsewhere quite thickly settled. If no sewage from towns and cities were permitted to be discharged into it the water would, never-

Mr. Ricketts.

theless, be unsafe for drinking purposes, if not filtered. This river discharges into the Hudson River below the intake of the Troy water-works. Below Troy, the cities of Albany, Hudson and Poughkeepsie filter the water pumped from the Hudson River. At least the last two have filtered it for years and the first will shortly have its extensive plant in operation. Under these circumstances it would be extremely difficult to force the great population of the towns and cities in the Mohawk Valley to purify their sewage before discharging it into the river, in order that its water might be more pure, but not pure enough to be drunk with safety.

In the "Report on the Chicago Drainage Canal by the Commission appointed by the Mayor of St. Louis, Mo., 1899," may be found the paragraph:

"By general law of the United States all cities must, sooner or later, be prevented from polluting the natural water courses of the country with sewage."

However much jurisdiction the United States may have in the Chicago Drainage Canal question, it would have to be considerably stretched to cover the case of a non-navigable stream, like the Mohawk, lying wholly within a single State and discharging into a river lying, as far as that part of it valuable for water-supply purposes is concerned, in the same State. And being thus practically a State question, how much chance is there that this large part of the population can, by act of Legislature, be put to great expense without proof that it is necessary.

When the writer became engineer of the Public Improvements Commission of the City of Troy, N. Y., and had, in consequence, to design a complete system of sewerage for the city, he was asked whether it would not be advisable to build an intercepting sewer along the river and purify the sewage of the whole city at the south end before discharging it into the Hudson River. This would have entailed pumping 9 000 000 galls. a day, exclusive of any rainfall, to a height of about 200 ft., purifying it, and discharging the effluent into the Hudson about 5 miles below the mouth of the sewage-laden Mohawk River. Twenty-five years ago the City of Troy began to pump most of its water supply from the Hudson above the mouth of the Mohawk, where the water was quite pure. Instead of doing this it could have obtained a bountiful supply by a gravity system at a reasonable cost. In the meantime the river has become more contaminated above the intake, by the sewage of towns which have since grown larger, and the quite pure water supply still exists in the highlands back of the city. Under these circumstances could Troy, in equity, compel the towns above to purify their sewage?

The writer has thus taken up the conditions existing in one neighborhood to show that no radical general rule can reasonably be made

regarding sewage purification. General laws, absolutely prohibiting the discharge of unpurified sewage into streams, would in many cases be destructive and unjust; and, in the design of a system of sewerage, it is well to remember that it is easy to put a community to unnecessary expense to meet possibilities which never materialize, and sometimes to prevent the construction of much-needed works by prohibitive and unnecessary conditions. Mr. Ricketts.

On the other hand, it is not necessary to state that many cases exist where the purification of sewage before its discharge into streams is advisable and necessary. This, of course, is particularly the case where the streams are small and the country thickly settled. Those in the neighborhood of Boston afford a good example. It also seems evident that even if a stream is not to be used for a water supply it should not be permitted to become a nuisance because of sewage discharged into it.

As to the pure-water question for cities, the writer believes filtration to be its coming solution. More or less pure water may be used without filtering if it comes from a source uncontaminated by the sewage of villages or cities, but the only way to be sure that it shall be reasonably pure is to filter it.

JAMES SMITH HARING, M. Am. Soc. C. E. (by letter).—There is a phase of the discharge of raw sewage into rivers and streams which was not mentioned in the oral discussion of this subject, that of the minimum flow, in either rivers or streams. Mr. Haring.

This is a matter of great importance in considering the question of permitting untreated sewage to enter sources of water supply, not only as regards the effect upon the purity of the supply for other localities, but also the relation which the amount of sewage passing into the stream has to the quantity of water flowing therein, to prevent the nuisance of the collection of undiluted sewage in the immediate vicinity.

Most western rivers are subject to large variations in both depth of flow and area covered during the periods of maximum and minimum seasons. Although the volume of water is calculated from the total quantity passing in the channel, yet it may be so divided and diverted as to leave the conditions attending the dilution of sewage quite at variance with the permissible allowance. Especially is this true of rivers having very rocky channels, in which the flow is concentrated at certain points into small cross-sections; while, at other places, the water is spread out over a very shallow but wide and stony bed and almost disappears. This is also true of a river of sandbars and marshes. The collection of sewage in beds of this character certainly emphasizes the necessity of compelling its treatment before discharging it into streams used for water supplies. It seems quite unnecessary to require any treatment of sewage before disposing of it in tidal

Mr. Haring. salt-water bodies. Cases might arise where sewage might be caught on a flood tide and carried back upon the shores and cause a nuisance, but the conditions would not be general, and the writer does not think that in the discussion of this subject such a contingency was anticipated.

The only way to make the purification of water supplies effective is to first prevent, by Federal laws, the pollution of rivers and streams. Too many of our rivers are in the jurisdiction of more than one State to make the State control of these matters effective, and the personal feelings of lawmakers are too largely acted upon by the fear of giving offense to some person or interest in their constituency to make a success of individual State legislation. Then, too, individual cities and towns will procrastinate to a degree almost, if not quite, criminal, rather than press on to a reform, or even to provide the means necessary to remedy or prevent the pollution of streams, because of the attending expense; and though conscious and confessing the, shall we call it, crime, permit it to go on. Only a general law, irrespective of State or city, can prevent effectually what will be in a few years, if it is not in some places already, an evil of great magnitude.

Filtration is destined to be the important agent to prevent wholesale contagion from water-borne diseases, even though it be compulsory by law to treat sewage before permitting it to flow into streams, and even though the effluent be purified "to a drinking-water standard," as one business concern engaged in that work now claims to do (though the standard may need qualification). The rapid development in the education of the people demands the filter as a guaranty of the best that can be had in water supply. Though sewage may be treated and made inoffensive by the expenditure of money, yet water supplies cannot be manufactured, and the daily increasing news of water famine all over the country admonishes us of such conditions.

Mr. Fuertes. JAMES H. FUERTES, M. Am. Soc. C. E. (by letter).—A brief analysis of what is already published on these subjects will be, it seems to the writer, of more value than the addition of new compilation to obscure further the simple principles governing the points under discussion.

The right of polluting streams, under certain conditions and to a certain extent, has been a large factor in the progress of all advanced countries. In some of our States the Mill Acts, passed to foster growing industries, would be inoperative if this right were not conceded. The term pollution is always comparative. No water found in Nature is pure, the purest being that from mountain springs. Going down the scale in the order of comparative pollution, would then be classed ordinary ground-waters, waters impounded in large storage reservoirs, waters of large normal rivers, waters of large lakes taken some distance from the shores, waters of upland streams, and, lastly, wells and bodies of water polluted directly by sewage matter near the point of abstraction.

Mr. Fuertes.

Prevention of pollution must, therefore, imply degree of prevention desirable, because all streams are already polluted by natural agencies beyond the control of man's legislation, unless flies and birds and winds and migratory animals can be legislated out of existence.

To prevent stream pollution absolutely would be undesirable. If a stream is not to be used for a water supply, or if its waters are not to enter into the composition of matters intended for human consumption, sufficient pollution prevention to insure its not being offensive in the slightest degree, or injurious to manufacturing interests, would be sufficient. This can be secured under the existing laws. If the water is to be used for a water supply, its protection must be more complete; but here, again, the laws are ample in scope. Not only would it be undesirable, but it would be impossible to secure the passage of absolute pollution-prevention legislation, because such laws would paralyze the manufacturing interests of the whole country, and would thereby arouse irresistible organized opposition. These views are expressed by the best expert opinion and by legislative bodies.

The discharge of a large amount of sewage into a small stream will, undoubtedly, make it offensive and unfit to drink; but the discharge of a much greater amount into the Upper Mississippi River, would be undetectable at its mouth. Thus, at New Orleans, the effect of the sewage discharged into it and its tributaries by all the cities between the Alleghenies and the Rockies is completely masked by the much greater relative pollution of the same kind, caused by surface washings from the water-sheds of these streams. In this connection, it will be interesting to observe whether or not the influence of the Chicago sewage, after it is directed into the Mississippi River, can be detected at St. Louis.

As a health protective measure, for cities on large rivers like the Mississippi, Ohio, Hudson, etc., it would be more efficacious and less expensive for all to discharge their crude sewage into the rivers and then purify their drinking water, than for all to purify their sewage and not their water supplies. On smaller streams both processes may be necessary. So far as the prevention of stream pollution is concerned, the laws are adequate; witness the recent cases of Danbury, Conn.; New Britain, Conn.; Santa Rosa, Cal., and numerous others.

The writer, in a statistical study compiled in 1896,* called attention to the extent and importance of pollution from surface washings, and since then has had verification of his deductions by seeing the same views expressed in the findings of a special investigation for the War

* "Water and Public Health. The Relative Purity of Waters from Different Sources."

Mr. Fuertes. Department on the cause of typhoid fever in the army camps during the late war, and in the report of the board of experts appointed to report on the improvement of the water supply of the City of Philadelphia.

The indications are that, with a little more popular education in these matters, the people will, before many years, demand the purification of all waters obtained from surface gathering grounds, rivers or lakes.

The purification of the sewage of large cities is not always practicable. So far as safe-guarding public health is concerned, it is vastly more important to sterilize all the air we breathe than to purify the sewage—for instance, of New York City. One would be just about as feasible, from a financial point of view, as the other. Probably there are, at least, one hundred times more deaths in the city resulting from breathing impure air than can possibly be traced to the combined effect of the sewage of the city and the infection of water and food supplies.

Filtration, if properly planned and conducted, is the best and most satisfactory way to purify drinking water, so far as we know, to-day. What the next fifty years will bring forth, however, is beyond the power of any mortal to prophesy. In the past two decades, so many of our standards have been changed, and so many useful scientific inventions have been perfected, that great advances are to be expected in every field.

There may be individuals in the next generation who will live to see 10 000 000 people resident in Greater New York. When that time arrives the water needed by the population will equal the present low-water flow of the Hudson River at Albany—draining over 8 000 square miles of country. The writer does not believe that any one now living can say how that water will be derived.